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**Toxicology Report No. S.0024589b-14  
U.S. Army Environmental Quality Technology  
Environmental Acquisition and Logistics  
Sustainment Program  
Zero Footprint Camp Program**

**September 2014**

**Shower Water Reuse System-  
Expanded Operations to Laundry Water**

**Work Unit WW13-01**

**Prepared by  
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**Toxicology Report No. S.0024589b-14  
Toxicology Assessment**

**Shower Water Reuse System-  
Expanded Operations to Laundry Water  
Work Unit WW 13-01**

**Zero Footprint Camp Program  
U.S. Army Environmental Quality Technology  
Environment Acquisition and Logistics Sustainment Program  
September 2014**

## **1 Summary**

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### **1.1 Overview**

Recycling of gray water (water that comes from sinks, showers, tubs, and washing machines and has not come into contact with fecal material) allows for more efficient use of non-potable water in bases or encampments and reduces the need for potable water to be used for purposes other than drinking or cooking. Efficient use of potable water is especially important in areas where availability and transport of drinking water is relatively scarce and unreliable. The shower water reuse system (SWRS) is approved and used currently to recycle shower water, but is now being considered as a treatment and filtration process for laundry water.

### **1.2 Purpose**

Research, development, testing, training, and use of substances potentially less hazardous to human health and the environment is vital to the readiness of the U.S. Army. Safeguarding the health of Soldiers, civilians, and the environment requires an assessment of alternatives before they are fielded. Continuous assessments begun early in the Research, Development, Testing and Evaluation (RDT&E) process can save significant time and effort during RDT&E, as well as over the life cycle of the items developed. Residues of chemicals of military interest that cost the U.S. Army billions of dollars and were part of mission essential activities have been found in soil, air, surface and ground water samples, creating environmental problems and interfering with training activities.

The Army Environmental Quality Technology (EQT) Zero Footprint Camp Program is dedicated to finding ways to reduce the environmental impact and logistics burden imposed by expeditionary facilities, while also finding replacements for substances causing environmental and/or occupational risks to health. As part of this program, each work unit is evaluated for environmental and occupational health impacts. The purpose of this Toxicity Assessment is to review the toxicity information currently available for the chemicals previously approved for the reuse of shower water and assess the possible human and environmental health effects of SWRS expansion for laundry water recycling, specifically evaluating the safety of the system's flocculating or coagulation products.

### 1.3 Conclusions

A preliminary assessment was conducted of possible effects on environmental quality and human health from the use of commercially available water treatment chemicals (RoQuest 6000, Magnasol 4000, Cat-Floc 8108 and Nalcolyte 8105). When used according to the manufacturer's guidelines the chemicals pose little to no risk as they are almost completely removed from the finished water after completion of the recycling process. Disposal of unused product and sludge from the intended application should follow pertinent guidelines.

### 1.4 Recommendations

The shower water reuse system (SWRS) expansion for laundry water recycling should continue in development. Personnel handling the products should use appropriate personal protective equipment. Army guidelines and regulations for water quality testing must be followed to ensure Soldier safety. Periodic review of relevant local, State and national waste water treatment disposal rules and regulations is recommended as these may change over time. The absence of the byproduct nitrosodimethylamine should be confirmed.

## 2 References

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See Appendix A for list of references.

## 3 Authority

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Funding for this work was provided under RDECOM MIPR No. 10453954. This Toxicology Assessment addresses, in part, the environmental safety and occupational health (ESOH) requirements outlined in Army Regulations (AR) (AR 40-5; AR 70-1; AR 200-1), Department of Defense Instruction (DoDI) 4715.4, and Army Environmental Requirement and Technology Assessment (AERTA) PP-5-07-02, Zero Footprint Camp, (AERTA 2012). It was conducted as part of an on-going effort by the U.S. Army Research, Development and Engineering Command (USARDECOM), Environmental Acquisition and Logistics Sustainment Program (EALSP; Mr. Erik Hangeland) and the Environmental Quality Technology (EQT), Pollution Prevention Team (P2TT), chaired by Dr. John LaScala. The Principle Investigator is Benjamin Thomas.

## 4 Background

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Current regulations require assessment of human health and environmental effects arising from exposure to substances in soil, surface water, and ground water. Applied after an item has been fielded, these assessments can reveal the existence of adverse environmental and human health effects that must be addressed, often at substantial cost. It is more efficient to begin the evaluation of exposure, effects, and environmental transport of military-related compounds/substances early in the RDT&E process in order to avoid unnecessary costs, conserve physical resources, and sustain the health of those potentially exposed.

In an effort to support this preventive approach, the U.S. Army Public Health Command has been tasked with creation of a phased process to reduce adverse ESOH effects impacting readiness, training, and development costs. This report represents the status of information available as of the publication date.

## 5 Statement of the Problem

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Potable water for essential activities (i.e. drinking, cooking and dental care) is a necessity for maintaining troop readiness and health. Although fully supplying a base or forward encampment with potable water for secondary purposes, such as showering and laundry is preferred, it is not always

feasible to do so. Reusing shower and laundry wastewater (gray water) represents an opportunity to reduce the total water requirement for military camps, but this reused water must be collected, treated, disinfected, and pumped back to the respective shower or laundry application. While shower and laundry gray water treatment equipment may produce water that meets drinking water standards, it may not be used for drinking, but only recycled and reused as non-potable water per Army Technical Bulletin Medical 577 (TB MED 577)(U.S. Army 2010). Additionally, recycling processes are maintained separately for shower and laundry water use and the output water is not to be mingled or redirected to uses other than its original application (i.e., these are closed loop systems).

According to TB Med 577, it is permitted to use non-potable water for showering or laundry with the following requirements: command and medical approval, appropriate signage indicating water is non-potable, daily monitoring of pH, chlorine, hardness, turbidity, coliform (bacterial contamination), etc., and appropriate record keeping of the monitoring findings. The purpose for these recycled water standards is to protect the health of personnel, including prevention of skin and eye irritation and disease transmission.

A treatment and filtration scheme currently used for recycling shower water is being considered for the recycling of laundry water. Both shower and laundry water (gray water) contain materials and constituents that may potentially clog the filtration process and must therefore be removed (Table 1). To remove the lint from the laundry source, commercially available flocculating or coagulation products aid sedimentation of these gray water components and are used prior to the final filtration steps. It is the coagulation products that are the subject of this toxicity assessment.

**Table 1. Source water contamination and exposure risk\***

	Possible Contaminants	Potential Risks
<b>Shower, Sinks and Bath</b>	<p>Fecal contamination and urine</p> <p>Chemicals from soaps, shampoos, dyes, mouthwash, toothpaste and cleaning products</p> <p>Hair, lint, body cells, oils, and dirt</p> <p>Blood and other wound exudates</p> <p>Trace amounts of pharmaceuticals</p>	<p>Fecal contamination is the greatest gray water risk to human health.</p> <p>Urine is generally sterile, unless a person suffers from a severe urinary tract infection.</p> <p>Bathroom gray water is generally well-diluted, reducing the immediate effects of chemicals in soaps and shampoos.</p>
<b>Laundry</b>	<p>Laundry detergents:</p> <ul style="list-style-type: none"> <li>- contain ammonia and other forms of nitrogen, phosphorus, and boron</li> <li>- high sodium and salinity</li> <li>- may have increased alkalinity and/or pH</li> </ul> <p>Bleaches and disinfectants may be present in laundry wastewater</p>	<p>Fecal contamination (and associated bacteria and viruses) may be present in wastewater from laundries washing soiled clothing.</p> <p>Laundry rinse water carries dilute soaps and dirt.</p> <p>Detergents, bleaches, and disinfectants are a significant risk to plants and soils, while some laundry contaminants (nutrients) can be beneficial</p>

\*Taken from Technical Information Paper (TIP) 32-002-0111- Non-potable water substitution and reuse in the field. PHC publication.

## 6 Methods

The chemicals/compounds that were considered and tested during this development effort are listed in Table 2. The individual substances were identified and researched using Chemical Abstracts Service registration numbers (CAS RN), synonyms and trade names, as applicable. This report addresses the substances being considered for use in the recycling treatment of laundry water.

Basic physical and chemical properties are usually determined by consulting authoritative primary and secondary sources when such information is available. The properties necessary to assess fate and transport in the environment (FTE) include:

- Molecular weight (MW).
- Henry's law constant ( $K_H$ ).
- Octanol-water partition coefficient ( $\log K_{OW}$ ).
- Water solubility.
- Boiling point (bp).
- Organic carbon partition coefficient ( $\log K_{OC}$ ).
- Vapor pressure (vp).

Information on combustion, explosion, and thermal decomposition products is also collected, if available. Toxicological information needed to estimate potential human health risks includes reported toxicity effects of acute, subacute, subchronic, and chronic exposures; potential for mutagenesis and carcinogenesis; and mode(s) and mechanisms of toxicity. Toxicological information was derived directly from primary sources when available.

**Table 2. Proposed composition of laundry water treatment scheme**

Product	Components	CAS# (if available)	Maximum Dosage*	Proposed Dosage**	Function/ Use
RoQuest 6000	<b>Organic coagulants</b> (polyamine = 1,2-Ethanediamine, polymer with 2-(chloromethyl) oxirane (epichlorohydrin) and N-methylmethanamine)	42751-79-1	5-35 ppm	300 µL/L	Coagulation and flocculation agent
	<b>Ferric sulfate (&gt;9.5%)</b>	10028-22-5			
Magnasol 4000	<b>Aluminum chlorhydrate</b>	12042-91-0	250 mg/L	300 µL/L	Coagulation agent
Cat-Floc 8108 Plus	<b>Poly(diallyldimethyl-ammonium chloride)</b> pDADMAC or pDMDAAC	26062-79-3	50 mg/L	150 uL/L	Flocculating agent
Nalcolyte 8105	<b>Epichlorohydrin dimethylamine</b>	25988-97-0	20 mg/L	60 µL/L	Coagulation and flocculation agent

**Table 2. Proposed composition of laundry water treatment scheme**

Product	Components	CAS# (if available)	Maximum Dosage*	Proposed Dosage**	Function/ Use
	polyamine (EPI-DMA)				

\* = NSF/ANSI 60; \*\* = personal communication from B. Thomas

Sources used in this search included publications from the U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry (ATSDR), and *The Merck Index* (O'Neil 2006). The Chemical Propulsion Information Agency's (CPIA), *Hazards of Chemical Rockets and Propellants* (CPIA 1985), and the U.S. Environmental Protection Agency's (USEPA) Drinking Water Health Advisory: Munitions (USEPA 1992), American Conference of Governmental Industrial Hygienists, Inc (ACGIH®) Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices, Code of Federal Regulations (CFR), the National Research Council's (NRC) Drinking Water and Health (NRC 1980), were also consulted. Commercial suppliers are sometimes contacted for results of in-house research that may not appear in the open literature. (ACGIH® is a registered trademark of the American Conference of Governmental Industrial Hygienists.)

Additional potential sources include the Defense Technical Information Center (DTIC), Food and Agriculture Organization of the United Nations (FAO), the World Health Organization (WHO), the International Agency for Research on Cancer (IARC), the International Chemical Safety Cards (ICSC) developed by the National Institute for Occupational Safety and Health (NIOSH), and the U.S. National Library of Medicine's Toxicology Data Network (TOXNET®) that provides access to information from the National Institutes of Health (NIH) and the USEPA. The TOXNET is a suite of individual databases including ChemIDPlusLite® (CIDPL) and ChemIDPlus® Advanced (i.e., chemical and registration numbers, and chemical identification and structure, searches respectively), Hazardous Substances Data Bank (HSDB®), Chemical Carcinogenesis Research Information System (CCRIS), Developmental and Reproductive Toxicology (DART/ETIC), Directory of Information Resources Online (DIRLINE®), Genetic Toxicology (GENE-TOX), Haz-Map (database linking chemicals, jobs and diseases), Household Products Databank (HPD) (potential health effects of chemicals in common household products), Integrated Risk Information System (IRIS), International Toxicity Estimates for Risk (ITER), Toxicology. Information Online (TOXLINE®), Toxic Release Inventory (TRI), and Lactation Database (LactMed) (database of drugs and other chemicals to which breastfeeding mothers may be exposed). The USEPA ECOTOXicology Database System (ECOTOX®) and the National Institute of Environmental Health Sciences (NIEHS) National Toxicology Program (NTP) databases were used. Primary sources are identified and retrieved using PubMed®, the Ovid® Technologies Journals, and the EBSCOhost® Research Database. (DTIC® is a registered trademark of the Defense Technical Information Center, TOXNET®, ChemIDPlusLite®, ChemIDPlus®, DIRLINE®, TOXLINE®, PubMed®, are registered trademarks U.S. National Library of Medicine; OVID®, is a registered trademark of Ovid Technologies, Inc.; and EBSCOhost® is a registered trademark of EBSCO Publishing.)

Persistence, bioaccumulation, human health toxicity, and ecotoxicity are evaluated using the general categories of hazard (e.g., low, moderate, and high) modified from Howe et al. (2006) . Table 3 describes the criteria used in the categorization, though the relative proportions of each substance were also factored into the final assessment.

**Table 3. Categorization Criteria used in the Development of Environmental Safety and Occupational Health Severity; modified from (Howe et al. 2006).**

	LOW	MODERATE	HIGH
PERSISTENCE	Readily biodegrades (<28d)	Degradation ½ life: water <40 d soil <120 d	Degradation ½ life: water >40 d soil > 120 d
TRANSPORT	Water sol. < 10 mg/L log Koc > 2.0	Water sol. 10-1000 mg/L log Koc 2.0-1.0	Water sol. > 1000 mg/L log Koc <1.0
BIOACCUMULATION	log Kow <3.0	log Kow 3.0-4.5	log Kow >4.5
TOXICITY	No evidence of carcinogenicity/mutagenicity; Subchronic LOAEL > 200 mg/kg-d	Mixed evidence for carcinogenicity/mutagenicity (B2, 2); Subchronic LOAEL 5-200 mg/kg-d	Positive corroborative evidence for carcinogenicity/mutagenicity; LOAEL < 5 mg/kg-d
ECOTOXICITY	Acute LC(D) <sub>50</sub> >1 mg/L or 1500 mg/kg; Subchronic EC <sub>50</sub> >100 µg/L or LOAEL >100 mg/kg-d	Acute LC(D) <sub>50</sub> 1-0.1 mg/L or 1500-150 mg/kg; Subchronic EC <sub>50</sub> 100-10 µg/L or LOAEL – 10-100 mg/kg-d	Acute LC(D) <sub>50</sub> <100 µg/L or <150 mg/kg; Subchronic LOAEL <10 mg/kg-d

Legend.

mg/L = milligrams per liter

LOAEL = lowest-observed adverse effect level

LC<sub>50</sub> = lethal concentration (concentration expected to result in 50 percent lethality to a population of test animals)LD<sub>50</sub> = lethal dose (dose expected to result in 50 percent lethality to a population of test animals)

mg/kg-d = milligram per kilogram per day

µg/L = microgram per liter

## 7 Results

### 7.1 Physical and Chemical Properties

Physical and chemical properties are summarized in Table 4. When data were not found, the indication “nd” (no data) is inserted. In some cases, the property named is not applicable to the substance being described. For example, if the substance is a nonvolatile solid or an inorganic salt, volatilization and bioconcentration will not be expected. In these cases, vapor pressure, K<sub>OW</sub>, K<sub>OC</sub>, and the Henry’s Law constant are negligible and will not apply. These properties are noted as “not applicable” or “n/a.”

### 7.2 Summaries

The summaries of the animal toxicity data are in Table 5. Assessments of human health and environmental toxicity for each of the formula components are presented in Tables 6 and 7, respectively. Each characterization is generally based on the criteria set forth in Table 3. The final risk characterization also incorporates assessment of the uncertainty associated with available data, the amount of each compound present in the formulation, and the nature of potential exposure associated with use of the end item.

### **7.3 RoQuest 6000**

#### **7.3.1 General Information**

According to the manufacturer's Material Safety Data Sheet (MSDS) (Avista Technologies 1999), the product is a clear, dark amber liquid with a mild odor. Appropriate PPE should be used when handling the concentrated liquid so that skin and eye contact is avoided. The cationic polymer in RoQuest 6000 is described as "polyamines". Based on the provided toxicity data at least one constituent is the monomer 1,2-ethanediamine polymerized with epichlorohydrin and N-methylmethanamine. The residual monomers in the RoQuest 6000 final product are anticipated to be low. The RoQuest 6000 product contains approximately 3-5 percent of the polymer mixture with the calculated monomer contributing less than 0.05 percent.

#### **7.3.2 Toxicology Data**

##### **7.3.2.1 Oral**

The concentrated product is toxic due to the corrosivity and high iron content; however, the dilute "as used" product is approved as a maximal drinking water treatment chemical of 285 mg/L according to NSF/ANSI 60 (NSF 2014)). The LD<sub>50</sub> for ferric sulfate was not available; however the estimated lethal human dose for soluble iron salts is 0.5-5 g/kg (HSDB 2013). Ingestion of less than 40 mg/kg may result in mild gastrointestinal tract irritation and the therapeutic dose for severe iron deficiency is 4-6 mg/kg-day (HSDB 2013). The LD<sub>50</sub> for the polymer provided in the MSDS is greater than 10 g/kg in rat and rabbit (Avista Technologies 1999).

##### **7.3.2.2 Inhalation**

No data for the product were available. Inhalation data for ferric sulfate were not available; however, the inhalation toxicity of iron salts (as dusts) was reported as irritating to the respiratory tract (HSDB 2013). Inhalation data provided in the product MSDS for the polymer are inadequately described and not useful for assessment; however, inhalation is not anticipated to be a major route of exposure.

##### **7.3.2.3 Dermal**

Chemical burns may result from contact with the concentrated product. Overexposure to low concentrations may cause reddening, inflammation and dermatitis.

##### **7.3.2.4 Ocular**

The mixture of substances in RoQuest 6000 is expected to be a severe ocular irritant and appropriate PPE should be used to prevent splashing of the concentrated product into the eyes.

##### **7.3.2.5 Reproduction and Development**

No toxicity data for the product were found.

##### **7.3.2.6 Mutagenicity**

No toxicity data for the product were found. The cationic monomer epichlorohydrin used for production of the polymer has mutagenic potential (see 7.6.2.6); however, the residual levels of monomers in the final concentrated product are sufficiently low to not be of concern.

### 7.3.2.7 Carcinogenicity

No toxicity data for the product were found. The cationic monomers used for production of the polymer may have carcinogenic potential however the residual levels of monomers in the final concentrated product are sufficiently low to not be of concern.

### 7.3.2.8 Ecotoxicology

The RoQuest 6000 product is used for the treatment of wastewater. The action of the product is to induce flocculation of suspended materials when mixed with water by generation of large particles that trap or bind to suspended solids, metals, etc. and settle out of the water column. Appropriate disposal of the sludge per local guidelines or regulations is necessary.

#### 7.3.2.8.1 Fate and Transport

The size of the flocculants prohibits mobility of the product - RoQuest 6000 sediments as a sludge and is not anticipated to enter the ground water.

#### 7.3.2.8.2 Ecotoxicology

The MSDS for RoQuest 6000 provides data for the monomers (as "cationic polymers") used to make the polymer. The marine ecotoxicity is low for copepods- the *Acartia tonsa* 48-hr LC<sub>50</sub> is 7283 mg/L and amphipods- the *Corophium volutator* 10-day LC<sub>50</sub> is 8871 mg/L. Toxicity is moderate for the marine algae (*Skeletonema costatum*) 72-hr EC<sub>50</sub>: 0.67 mg/L. The product is moderately toxic to fresh water fish with the 96-hour LC<sub>50</sub> for bluegill and trout reported as 0.90 and 0.60 mg/L, respectively. The toxicity values are caveated with the statement that natural waters would contain suspended solids and dissolved organic materials (both the target of RoQuest flocculation) and these materials would reduce the effective concentration of the polymer and therefore its toxicity.

#### 7.3.2.8.3 Degradation and Treatment

Sludge generated from the water treatment process would be subject to photolysis and potentially microbial breakdown. Depending on the source water for the treatment process, leachate from the sludge may contain residual contaminants such as metals and pesticides.

## 7.4 Magnasol 4000™

### 7.4.1 General Information

Mangasol 4000™ is manufactured by BASF for water treatment applications as an enhancer for turbidity and suspended solids removal. It consists of a single chemical compound, aluminum chlorhydrate (frequently known as ACH industrially). It is a polymeric form of aluminum chloride in which some chloride species have been replaced by hydroxide ions. Aluminum chlorhydrate is a commonly used flocculating agent and is the active ingredient in some antiperspirant formulations. Aluminum occurs ubiquitously in the environment in the form of silicates, oxides and hydroxides (HSDB 2013).

### 7.4.2 Toxicology Data

#### 7.4.2.1 Oral

The oral toxicity of aluminum chlorhydrate was not identified. No LD<sub>50</sub> for aluminum in humans has been determined, but aluminum-containing food additives are considered Generally Recognized As

Safe by the U.S. Food and Drug Administration (ATSDR 2008). Toxicity data were available for "aluminum compounds" in HSDB. Aluminum is poorly absorbed in the intestinal tract; therefore, toxicity does increase with solubility. For example, the LD<sub>50</sub> of aluminum chloride is 770 mg (aluminum)/kg in mice (HSDB 2013). Absorbed aluminum is eliminated via the kidneys and individuals with chronic renal failure are more sensitive to aluminum toxicity (HSDB 2013). Dietary intake of aluminum ranges from 2-14 mg/day and may be as high as 126-5000 mg/day when aluminum containing medications are considered. Users of aluminum-containing medications that have normal kidney function can ingest large quantities of aluminum without ill effect.

#### **7.4.2.2 Inhalation**

Toxicity data for aluminum salts were not identified. Chronic aluminum fume and/or dust exposure in occupational scenarios may result in fume fever or severe pulmonary reactions including fibrosis and emphysema (Gosselin et al. 1984). Respiratory effects typically associated with inhalation of particulates and lung overload have been observed in animals. The pulmonary toxicity of alchlor, a propylene glycol complex of aluminum chlorhydrate and a common component of antiperspirants, was examined in hamsters in a series of studies (Drew et al. 1974). Three-day inhalation exposure to 31 or 33 mg Al/m<sup>3</sup> resulted in moderate-to-marked thickening of the alveolar walls due to neutrophil and macrophage infiltration and small granulomatous foci at the bronchioalveolar junction. A decrease in the severity of the pulmonary effects was observed in animals killed 3, 6, 10, or 27 days after exposure termination. The ACGIH TWA for aluminum chloride hydroxide (Al<sub>2</sub>Cl(OH)<sub>5</sub>) is 1 mg/m<sup>3</sup> (HSDB 2013).

#### **7.4.2.3 Dermal**

In solution, aluminum is not particularly irritating; however, dry aluminum dusts and fumes may cause dermal irritation (HSDB 2013).

#### **7.4.2.4 Ocular**

In solution, aluminum is not particularly irritating; however, dry aluminum dusts and fumes may cause ocular irritation (HSDB 2013).

#### **7.4.2.5 Reproduction and Development**

Numerous studies have been conducted with a variety of aluminum compounds. The results are equivocal with some studies suggestive of neurobehavioral effects in offspring and others failing to demonstrate any effects (HSDB 2013).

#### **7.4.2.6 Mutagenicity**

Aluminum was not mutagenic in bacteria and it has not been demonstrated to induce mutations or transformations in *in vitro* assays (HSDB 2013).

#### **7.4.2.7 Carcinogenicity**

Aluminum does not appear to be carcinogenic to humans; however, chromosomal aberrations in bone marrow cells of exposed mice and rats have been observed (HSDB 2013). In rats, aluminum may have a direct toxic effect on erythroid progenitors (Vittori et al. 1999).

#### **7.4.2.8 Ecotoxicology**

#### 7.4.2.8.1 Fate and Transport

Aluminum is a ubiquitous natural element found in the form of silicates, oxides and hydroxides. At pH values greater than 5.5 aluminum compounds will be predominantly insoluble. However, high levels of dissolved organic material can lead to increased concentrations of dissolved aluminum (IPCS-INCHEM 1997).

#### 7.4.2.8.2 Ecotoxicity

The 96-hour LC<sub>50</sub> for Fathead minnow (*P. promelas*) and Atlantic silverside (*M. menidia*) is reported to be 609 and >2000 mg/L respectively (BASF 2011). The *D. magna* 48-hour LC<sub>50</sub> is 397 mg/L and the mysid shrimp 96-hour LC<sub>50</sub> is 1360 mg/L (BASF 2011).

#### 7.4.2.8.3 Degradation and Treatment

Aluminum is an abundant naturally occurring element and does not degrade. ACH in the presence of hydroxide or diluted in water readily forms the hydroxide polymorphs bayerite or gibbsite, respectively (Teagarden et al. 1981).

### 7.5 Cat-Floc 8108 Plus

#### 7.5.1 General Information

Cat-Floc 8108 Plus is a cationic flocculent that is a polymer of diallyldimethylammonium chloride (DADMAC), a quaternary ammonium compound. It contributes to charge neutralization and acts as a promoter for anionic retention aids. The Cat-Floc product is certified by the NSF to meet the NSF/ANSI standard 60: Drinking water treatment chemicals. As such, the residual monomer concentration is less than one percent of the mixture and when used according to the manufacturer's dosing rate any monomer in the finished product is below the maximum level allowed for drinking water standards.

#### 7.5.2 Toxicology Data

There are multiple names/synonyms for poly (p) DADMAC to include pDADMAC, pDMAAC, polyquaternium 6, Quanterium 40, etc. The CAS number 26062-79-3 was used to compare chemical names and compile data from disparate synonyms.

##### 7.5.2.1 Oral

The lethal dose for mammals has been determined for pDMAAC and is reported in CIDPLplus. In mice, the LD<sub>50</sub> is 1720 mg/kg and in guinea pig and rat it is 3250 and 3000 mg/kg, respectively (CIDPL 2013). In contrast, the MSDS for the product reports an LD<sub>50</sub> of 14.6 g/kg in rat (NALCO 2010). It is unclear what may account for the discrepancy- the MSDS reports the toxicity of the "product" which contains approximately 40 percent active ingredient and would thereby nominally increase the toxicity to 5840 mg/kg.

##### 7.5.2.2 Inhalation

No toxicity data were found. Inhalation of a cationic surfactant such as DMAAC is likely to cause mild irritation to the respiratory tract.

### 7.5.2.3 Dermal

The product MSDS reports Cat-Floc is not a primary skin irritant (NALCO 2010).

### 7.5.2.4 Ocular

The product MSDS reports Cat-Floc is a mild primary eye irritant (NALCO 2010).

### 7.5.2.5 Reproduction and Development

No toxicity data were found.

### 7.5.2.6 Mutagenicity

No toxicity data were found.

### 7.5.2.7 Carcinogenicity

No toxicity data were found.

### 7.5.2.8 Ecotoxicology

#### 7.5.2.8.1 Fate and Transport

The polymer has low volatility and would not be expected to partition to the atmosphere. The polycationic nature of the molecule indicates that it would bind to soils and settle out of the water column as it came into contact with dissolved solids and humic material.

#### 7.5.2.8.2 Ecotoxicity

The MSDS for Cat-Floc provided ecotoxicity data (NALCO 2010). Several acute fish studies have been performed. The 96-hour LC<sub>50</sub> were reported for the following species: Bluegill (*Lepomis macrochirus*) 1.07 mg/L, Rainbow trout (*Oncorhynchus mykiss*) 0.76 mg/L, Zebrafish (*Danio rerio*) 10-100 mg/L, and Inland Silverside 4989 mg/L. Invertebrate data included *Daphnia* 48-hour LC<sub>50</sub> exposures conducted in either clean, 50 mg/L clay or 1000 mg/L clay. The inclusion of clay is designed to represent organic matter that would reduce the toxicity of the compound. For *Daphnia*, the LC<sub>50</sub> in clean water was 1.8 mg/L, toxicity in 50 mg/L clay was 3.7 mg/L and toxicity in 1000 mg/L decreased further to 49.6 mg/L. Mysid shrimp 96-hour LC<sub>50</sub> in clean water was 92 mg/L. *Ceriodaphnia dubia* were more sensitive with a 48-hour LC<sub>50</sub> of 0.510 to 0.770 mg/L depending on water hardness. pDMAAC (as VeliGON™) is used as a molluscicide for the removal of zebra mussel and *Corbicula veligers* (free swimming Asian clam larva) (Sprecher and Getsinger 2000). For small releases the dissolved solid and organic content of the water would likely decrease toxicity. For larger releases where Cat-Floc might be more than sufficient to remove the suspended material, the clean water toxicity values are more relevant. The polymer (or "representative polymer") was tested on earthworms with a reported no-observed-effect-concentration (NOEC) of 1000 mg/L (NALCO 2010).

#### 7.5.2.8.3 Degradation and Treatment

The extent of biodegradation of the monomer (DADMAC) is anticipated to be low (days to weeks) based on EPI Suites analysis (USEPA 2013). The polymer is subject to limited hydrolysis and oxidation. Disposal of the used polymer (as sludge) should follow any local, regional and national policies.

## 7.6 Nalcolyte 8105

### 7.6.1 General Information

Nalcolyte™ 8105 is a polyamine liquid cationic polyelectrolyte of epichlorohydrin dimethylamine polyamine (EPI-DMA). It is certified to comply with 40 CFR 141.111 requirements for percent monomer and dose--currently not to exceed 0.01 percent epichlorohydrin when dosed at its maximum use of 20 mg/L (NSF 2014). The product is also acceptable under 21 CFR 176.170 and 21 CFR 176.180 when used in the manufacture of food grade paper and paperboard with a not to exceed one percent by weight of the finished paper and paperboard (CFR 2009; CFR 2014).

### 7.6.2 Toxicology Data

#### 7.6.2.1 Oral

No toxicity data were available for the polymer. The manufacturer's MSDS for an unidentified "similar substance" indicates the rat LD<sub>50</sub> was > 5000 mg/kg (NALCO 2000).

#### 7.6.2.2 Inhalation

No data were located for the polymer. Inhalation is not expected to be a significant source of exposure.

#### 7.6.2.3 Dermal

No data were located for the polymer. The manufacturer's MSDS for an unidentified "similar substance" indicates the rabbit LD<sub>50</sub> was > 2000 mg/kg (NALCO 2000). The MSDS also reports that a substance similar to poly-EPI-DMA was a minimal skin irritant--Draize score = 0.1/8.0.

#### 7.6.2.4 Ocular

No data were located for the polymer. The MSDS provides data for an unidentified "similar substance" and rates poly-EPI-DMA as minimally irritating (NALCO 2000).

#### 7.6.2.5 Reproduction and Development

No data were located for the polymer.

#### 7.6.2.6 Mutagenicity

No data were located for the polymer. One of the chemicals in the monomeric mixture, epichlorohydrin (CAS # 106-89-8) is genotoxic (HSDB 2013).

#### 7.6.2.7 Carcinogenicity

No data were located for the polymer. One of the chemicals in the monomeric mixture, epichlorohydrin (CAS # 106-89-8) causes tumors in animals and is classified as a probable human carcinogen (HSDB 2013). The residual amount of epichlorohydrin monomer in the product is regulated and cannot exceed 0.1 percent. The other constituent of the mixture, dimethylamine, has the potential to be converted to nitrosodimethylamine (NDMA) when reacted with nitrogen oxides, nitrous acid or nitrite salts- conditions which are likely present during the SWRS process. NDMA is classified as Group B2, probable human carcinogen and has an inhalation unit risk of 0.014 ug/m<sup>3</sup> (IRIS 2014).

### **7.6.2.8 Ecotoxicology**

#### **7.6.2.8.1 Fate and Transport**

The used product forms large particles that sediment out of the water column. It is not anticipated to enter ground water. Although the individual monomers in the parent formulation have volatility, the as-used polymer product has minimal volatility and would not significantly partition to the atmosphere.

#### **7.6.2.8.2 Ecotoxicity**

The poly-EPI-DMA is acutely toxic to aquatic organisms and releases into natural bodies of water are to be avoided. The MSDS provides the results aquatic toxicity testing. In Fathead minnow (*Pimephalas promelas*) the 96-hour  $LC_{50}$  is 0.380 mg/L and in Rainbow trout (*Oncorhynchus mykiss*) the 96-hour  $LC_{50}$  is 0.097 mg/L. *Daphnia* 48-hour  $LC_{50}$  is 0.700 mg/L.

#### **7.6.2.8.3 Degradation and Treatment**

Degradation of the polymer is influenced by pH and oxidation (Park et al. 2014). The polymer is resistant to microbial breakdown. It is subject to limited decay via photolysis (Deng et al. 2014). Disposal should conform to pertinent local regulations and guidelines.

**Table 4: Physical and Chemical Properties.**

Compound	Molecular Weight *	pH	Boiling Point (°C)	Aqueous solubility (mg/L) @ 25 °C	log Kow	log Koc	Henry's Law Constant (atm-m <sup>3</sup> /m @ 25 °C)	vp (mmHg)
<b>RoQuest 6000</b>								
Organic coagulant (polyamine)	1,000,000**	2.0-3.0 (1% solution)**	~100**	Soluble**	nd	nd	n/a	n/a
Monomer 1,2-Ethanediamine, polymer with epichlorohydrin and dimethylamine	197.71 (est.)	nd	~100**	Soluble**	nd	nd	nd	nd
Ferric sulfate	399.88 <sup>a</sup>	n/a	1178 (dec.) <sup>b</sup>	Slowly soluble <sup>b</sup>	n/a	n/a	n/a	n/a
<b>Magnasol 4000</b>								
Aluminum chlorhydrate	174.45 <sup>c</sup>	3-4	~100	soluble	n/a	n/a	n/a	n/a
<b>Cat-Floc 8108 Plus</b>								
Polydiallyldimethyl ammonium chloride (polyDADMAC)	50,000-3,000,000	6.5	~100	soluble	nd	nd	nd	nd
DADMAC monomer	161.67	6.5	n/a	soluble	-2.49 (est.)	nd	7.2xE-12 (est.)	3.53xE-6 (est.)
<b>Nalcolyte 8105</b>								
Epichlorohydrin dimethylamine polyamine (EPI-DMA)	<50,000 <sup>d</sup>	7-8.5	>100	soluble	nd	nd	nd	nd
Epichlorohydrin	92.52 <sup>a</sup>	n/a	116 <sup>b</sup>	6.6xE+4 <sup>c</sup>	0.45 <sup>c</sup>	0.67 <sup>e</sup>	3.04xE-05 <sup>c</sup>	16.4 <sup>c</sup>
Dimethylamine	45.08 <sup>c</sup>	n/a	6.8 <sup>c</sup>	1.63xE+06 <sup>c</sup>	-0.38 <sup>c</sup>	2.64 <sup>e</sup>	1.77E-05 <sup>c</sup>	nd
n/a = not applicable; nd = no data; est. = estimated; Exp = experimental; dec. = decomposes; * = extent of polymeric state affects specific physicochemical properties (Hendricks 2006); ** = MSDS								

<sup>a</sup> O'Neil, 2006<sup>b</sup> Dean, 1992<sup>c</sup> CIDPL, 2013<sup>d</sup> Kim, et al., 2014<sup>e</sup> USEPA, 2013

Table 5. Toxicity Data.

Compound	Acute LD <sub>50</sub> (mg/kg)	Chronic NOAEL/LOAEL (mg/kg-d)	Inhalation LC <sub>50</sub>	Dermal	Ocular	Mutagenicity	Carcinogenicity
RoQuest 6000	Polymer: >10,000 (rabbit; rat) Iron salt 168 (IP; mouse) <sup>a</sup>	nd	nd	nd; compound is intrinsically corrosive	nd; compound is intrinsically corrosive	nd	nd
Magnasol 4000	>2000 (rat) <sup>b</sup>	nd	nd	>2000 (rat) <sup>b</sup>	nd	Negative (Ames) Negative mouse lymphoma assay <sup>c</sup>	Equivocal
Cat-Floc 8108 Plus	1720 (mouse); 3250 (guinea pig); 3000 (rat) <sup>d</sup> 14600 (product- in rat) <sup>e</sup>	nd	nd	Negative <sup>e</sup>	Mild irritant <sup>e</sup>	nd	nd
Nalcolyte 8105	>5000 (rat) <sup>f</sup>	nd	nd	Negative <sup>f</sup>	Mild irritant <sup>f</sup>	nd	nd
Epichlorhydrin	195 (mouse) 280 (guinea pig) <sup>d</sup>	15 mg/kg-day reversible infertility <sup>c</sup>	20 ppm (human TC <sub>Lo</sub> ) 720000 (mouse LC <sub>Lo</sub> ) <sup>d</sup>	250 (mouse LD <sub>50</sub> ) 515 (rabbit LD <sub>50</sub> ) <sup>d</sup>	Irritant; corneal injury (rabbit) <sup>c</sup>	Positive in vitro sister chromatid exchange, Positive in Ames assay <sup>c</sup>	Positive at site of exposure- mouse skin, rat forestomach <sup>c</sup>
Dimethylamine	698 (rat) 316 (mouse)	97 ppm inhalation- corneal injury and liver effects (rats, mice, guinea pig) <sup>c</sup>	>5420 ppm (mice) <sup>c</sup>	LD <sub>50</sub> 3900 (rat) Positive- corrosive and sensitizer rabbit and guinea pig <sup>c</sup>	Positive- corrosive rabbit and guinea pig <sup>c</sup>	Negative Ames assay <sup>c</sup>	Negative 2 yr inhalation cancer study mice and rats <sup>c</sup>

<sup>a</sup> Avista Technologies, 1999<sup>b</sup> BASF, 2011<sup>c</sup> HSDB, 2013<sup>d</sup> CIDPL, 2013<sup>e</sup> NALCO, 2010<sup>f</sup> NALCO, 2000

**Table 6. Toxicity Assessment.**

Compound	Oral	Inhalation	Dermal	Ocular	Carcinogenicity	Comments
RoQuest 6000	Low	Low	Moderate	Moderate	Low	Avoid skin and eye contact with undiluted product.
Magnasol 4000	Low	Low	Low	Moderate	Low	Avoid ocular contact with undiluted product.
Cat-Floc 8108 Plus	Low	Low	Low	Moderate	Low	Avoid ocular contact with undiluted product.
Nalcolyte 8105	Low	Low	Low	Moderate	Low	Avoid ocular contact with undiluted product.
**Epichlorhydrin	Low	Low	Low	Low	Low	Although the neat chemical is toxic, the residual monomer concentration and final concentration limit in the finished water are sufficiently low to be below a threshold of concern.
**Dimethylamine	Low	Low	Low	Low	Low	

\* = based on weight of evidence, physicochemical properties and professional judgment using criteria set forth in Table 2; \*\*parent monomer used in synthesis of Nalcolyte 8105 and RoQuest 6000.

**Table 7. Ecotoxicology Assessment.\***

Compound	Aquatic	Invertebrates	Plants	Mammals	Birds	Comments
RoQuest 6000	Moderate (Bluegill and trout)	Low (copepods and amphipods)	Moderate (marine algae)	Low (rat)	Low *	Avoid release into natural streams and bodies of water.
Magnasol 4000	Low (Fathead minnow and Atlantic silverside)	Low (Daphnia and mysid shrimp)	Low *	Low (rat)	Low *	
Cat-Floc 8108 Plus	Low-Moderate (Bluegill, Rainbow trout, Zebrafish Inland Silverside)	Low (Daphnia and mysid shrimp) Moderate (Ceriodaphnia)	Low *	Low (rat, mouse, guinea pig)	Low *	
Nalcolyte 8105	Moderate (Fathead minnow) High (trout)	High (Daphnia)	Low *	Low (rat)	Low *	
Epichlorhydrin (residual monomer)	Low (Bluegill, Rainbow trout, Zebrafish Inland Silverside)	Low (Daphnia and Ciliates)	Low (green and blue green algae)	Moderate (rat)	Moderate *	Regulated by Clean Water Act

\* = based on weight of evidence and professional judgment using criteria set forth in Table 2.

## 8. Discussion

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### 8.1 General

The majority of the individual components of WW 13-01 have established manufacturing, occupational safety, regulatory, and human health histories, although not necessarily in these combinations or uses.

### 8.2 Regulations and Standards

A search for regulatory requirements under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), Toxic Substances Control Act (TSCA), Resource Conservation and Recovery Act (RCRA), Comprehensive Environmental Response, Compensation, and Liability Act/Superfund Amendments and Reauthorization Act (CERCLA/SARA), and the Clean Water Act related to components of this formulation resulted in the information below. Industrial standards set by the National Institute of Occupational Safety and Health (NIOSH) and the OSHA are also included. The water treatment chemicals investigated for this report have associated NSF/ANSI 60 standards. NSF standards provide basic criteria to promote and protect public health (NSF 2013). These NSF standards were developed using a voluntary consensus process. NSF/ANSI 60 establishes the minimum requirements for the control of potential adverse human health effects from products added to water for its treatment.

#### 8.2.1 RoQuest 6000

Ferric sulfate- the EPA drinking water guidelines state 300 ug/L for soluble iron. Ferric sulfate is designated as a hazardous substance 311(b)(2)(A) of the Federal Water Pollution Control Act and further regulated by the Clean Water Act Amendments of 1977 and 1978. These regulations apply to discharges of this substance. This designation includes any isomers and hydrates, as well as any solutions and mixtures containing this substance.

#### 8.2.3 Magnasol 4000

Aluminum chlorhydrate- the product is not hazardous. The final maximum concentration of aluminum in finished drinking water is not to exceed 2 mg/L (NSF 2014).

#### 8.2.3 Cat-Floc 8108 Plus

Polydiallyldimethylammonium chloride (polyDADMAC)- according to the MSDS the product is not a hazardous waste as defined by RCRA 40CFR261 (NALCO 2010).

#### 8.2.4 Nalcolyte 8105

Nalcolyte is toxic to aquatic organisms and should not be released into natural bodies of water. The percent residual epichlorhydrin monomer is regulated and specific manufacturing plants produce the Nalcolyte product that is certified to comply with 40 CFR 141.111 requirements for percent monomer and dose.

### 8.3 Summary and Conclusions

#### 8.3.1 General

The toxicity of the products used for recycling and reuse of laundry water are generally low. Technicians and equipment operators should follow guidance and instructions for properly handling

the neat products as there is the potential for eye and skin injury if mishandled. Cationic flocculating agents have the potential to interact with the gill structures of aquatic organisms and inhibit respiration (Albassam et al. 1987). The used product will be collected as sludge at the end of the water treatment process. Disposal of the sludge should follow all applicable guidelines and regulations. The sludge should not be disposed of in a manner that would introduce it to streams, rivers, or natural bodies of water due to its intrinsic aquatic toxicity. The Army has specific regulations for water quality and reuse. They are described in USACHPPM IP 31-027, "Criteria for Recycle of Gray Water for Shower Use," and implemented in Army Surgeon General Memorandum DASG-PPM-NC, 13 August 2004. There are testing criteria for several water parameters including pH, turbidity, residual chlorine, etc. and the appropriate monitoring and reporting in accordance with Army regulations/guidance should be followed.

## **9 Recommendations**

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Given the information provided, the formulations proposed in WW 13-01 are not considered to be of significant environmental or human health concern. There are regulations regarding residual monomer for Nalcolyte (epichlorhydrin) and the RoQuest 6000 formulation also contains epichlorhydrin. It should be noted that the allowable percent residual monomer may inadvertently be exceeded when multiple formulations are combined. The use of the ingredient dimethylamine should be addressed, as well. It is recommended that the finished water that is returned for use in the laundry and shower water systems be tested for the presence of the water treatment byproduct, nitrosodimethylamine. While it is likely that the NDMA will be below the detection limit and below a threshold of concern, its absence should be confirmed. Soldier uniforms have insect repellants and chemicals that reduce infrared detection built into the fabric. It should be confirmed that the water treatment scheme does not degrade these intrinsic features of the uniform.

## 10 Point of Contact

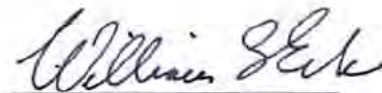
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## APPENDIX A

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